

# Review of the ant genus *Nesomyrmex* Wheeler, 1910 (Hymenoptera, Formicidae, Myrmicinae) from the Arabian Peninsula

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## Abstract

In this study, we review the Arabian species of the ant genus *Nesomyrmex* Wheeler. We provide species reviews for the two previously known species, *N. angulatus* (Mayr, 1862) and *N. humerosus* (Emery, 1896) and describe a new species *N. zaheri* **sp. n.** from Yemen based on the worker caste. An illustrated key to the Arabian species of the genus and montage photos of all three species are provided.

## Keywords

Afrotropical Region, identification key, systematics, taxonomy, new species, Kingdom of Saudi Arabia, Asir Province

## Introduction

The myrmicine ant genus *Nesomyrmex* Wheeler, 1910 is distributed in the subtropical and tropical regions of the Neotropical, Afrotropical, and Malagasy Regions. With currently 80 valid species, the genus is comparatively species-rich (Bolton 2017).

In the last decade the taxonomy of the Old World fauna, especially the Afrotropical Region, has received much attention. Bolton (1982) and Snelling (1992) initially recognized ten Afrotropical species and subsequently Mbanyana and Robertson (2008) revising the South African taxa described 15 new species, increasing the number of species in this region to 25 species. Recently, Hita Garcia et al. (2017) reviewed the taxonomy of the genus for the Afrotropical Region proposing four species groups, and revising the *N. angulatus* species group, bringing the total number of species to 26. Recently, the Malagasy *Nesomyrmex* fauna was revised by Csősz and Fisher (2015, 2016a, b, c, d). They divided the genus into five species groups and recognized 33 species, of which they described 29 as new.

Little taxonomic or biogeographical information is currently available for the Arabian *Nesomyrmex*, of which only two species are known. The wide-spread and common species, *N. angulatus* (Mayr 1862) has been recorded from the Kingdom of Saudi Arabia, Oman, and Yemen, whereas the rare *N. humerosus* (Emery, 1896) is only known from one collection from Yemen (e.g. Collingwood 1985, Collingwood and Agosti 1996, El-Hawagry et al. 2013, Borowiec 2014, Hita Garcia et al. 2017, Sharaf et al. 2017a).

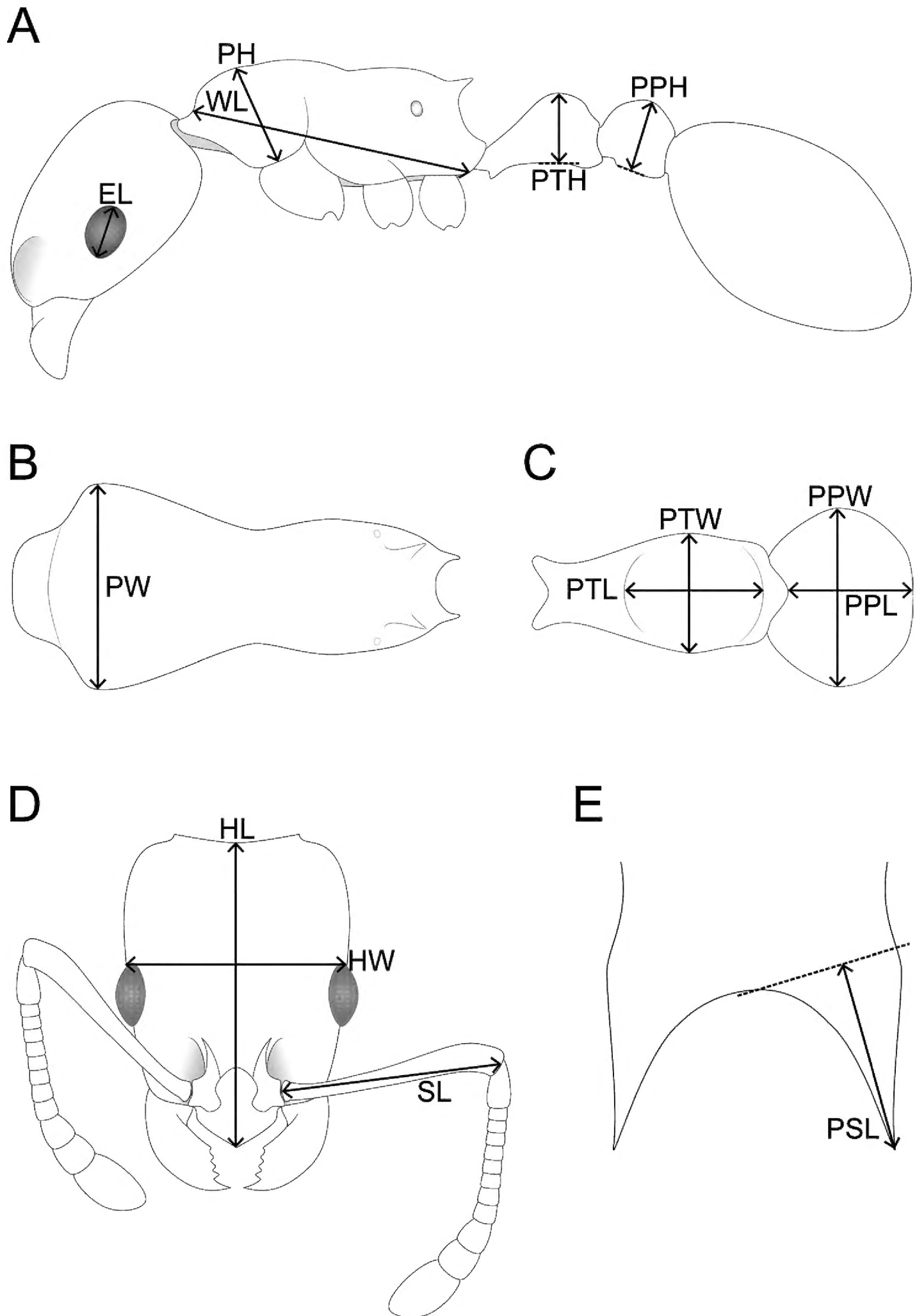
While treating the Arabian species of *Temnothorax* Mayr, 1861 (Sharaf et al. 2017b), the first author examined a misidentified specimen in the King Saud University Museum of Arthropods (KSMA). Further study indicated that this specimen was not a *Temnothorax* but clearly represented an undescribed species of *Nesomyrmex*. In this study, we recognize this specimen as a new species and review the species from the Arabian Peninsula. We provide species accounts for the two previously known species and a detailed description for the new species *N. zaheri* sp. n.. The erroneous record of *Nesomyrmex denticulatus* (Mayr, 1901) by El-Hawagry et al. (2016) is rectified here. The species is known only from South Africa and its distributional record from Arabian Peninsula is incorrect. Herein we present a first illustrated identification to the worker caste for the Arabian Peninsula, as well as montage images for all three species.

## Material and methods

Morphological examinations were made using a Nikon SMZ 1500 stereo zoom microscope. The images of the type are available at AntWeb (<https://www.antweb.org>). General terminology for ant morphology is based on Bolton (1982, 1994), and for the description of degrees of inclination of pilosity we follow Wilson (1955). Measurements and indices are presented as minimum and maximum values with arithmetic means in parentheses, and all measurements are expressed in mm to two decimal places. The following measurements and indices used in this study (see Fig. 1) follow Hita Garcia et al. (2017):

**HL** Head length: maximum distance from the midpoint of the anterior clypeal margin to the midpoint of the posterior margin of head, measured in full-

	face view. Impressions on the anterior clypeal margin and the posterior head margin reduce head length.
<b>HW</b>	Head width: width of the head directly behind the eyes measured in full-face view.
<b>SL</b>	Scape length: maximum scape length excluding basal condyle and neck.
<b>EL</b>	Eye length: maximum diameter of compound eye measured in oblique lateral view.
<b>PH</b>	Pronotal height: maximum height of the pronotum measured in lateral view.
<b>PW</b>	Pronotal width: maximum width of the pronotum measured in dorsal view.
<b>WL</b>	Weber's length: diagonal length of the mesosoma in lateral view from the posteroventral margin of propodeal lobe to the anterior-most point of pronotal slope, excluding the neck.
<b>PSL</b>	Propodeal spine length: in dorsofrontal view the tip of the measured spine, its base, and the centre of the propodeal concavity between the spines must all be in focus. Using a dual-axis micrometre the spine length is measured from the tip of the spine to a virtual point at its base where the spine axis meets orthogonally with a line leading to the median point of the concavity.
<b>PTH</b>	Petiolar node height: maximum height of the petiolar node measured in lateral view from the highest (median) point of the node to the ventral outline. The measuring line is placed at an orthogonal angle to the ventral outline of the node.
<b>PTL</b>	Petiolar node length: maximum length of the dorsal face of the petiolar node from the anterodorsal to the posterodorsal angle, measured in dorsal view excluding the peduncle.
<b>PTW</b>	Petiolar node width: maximum width of the dorsal face of the petiolar node measured in dorsal view.
<b>PPH</b>	Postpetiole height: maximum height of the postpetiole measured in lateral view from the highest (median) point of the node to the ventral outline. The measuring line is placed at an orthogonal angle to the ventral outline of the node.
<b>PPL</b>	Postpetiole length: maximum length of the postpetiole measured in dorsal view.
<b>PPW</b>	Postpetiole width: maximum width of the postpetiole measured in dorsal view.
<b>OI</b>	Ocular index: $EL / HW * 100$
<b>CI</b>	Cephalic index: $HW / HL * 100$
<b>SI</b>	Scape index: $SL / HW * 100$
<b>DMI</b>	Dorsal mesosoma index: $PW / WL * 100$
<b>LMI</b>	Lateral mesosoma index: $PH / WL * 100$
<b>PSLI</b>	Propodeal spine index: $PSL / HL * 100$
<b>LPeI</b>	Lateral petiole index: $PTL / PTH * 100$
<b>DPeI</b>	Dorsal petiole index: $PTW / PTL * 100$
<b>LPpI</b>	Lateral postpetiole index: $PPL / PPH * 100$
<b>DPpI</b>	Dorsal postpetiole index: $PPW / PPL * 100$
<b>PPI</b>	Postpetiole index: $PPW / PTW * 100$



**Figure 1.** Schematic line drawings of a *Nesomyrmex* species illustrating the measurements used (reproduced from Hita Garcia et al. 2017). **A** Body in profile with measuring lines for EL, WL, PH, PTH, and PPH **B** Mesosoma in dorsal view with measuring line for PW **C** Petiole and postpetiole in dorsal view with measuring lines for PTL, PTW, PPL, PPW **D** Head in full-face view with measuring lines for HL, HW, and SL **E** Dorsocaudal view of the propodeum with measuring line for PSL.

## Abbreviations

Throughout the text we abbreviate the castes in the following way: “w” for worker(s), “q” for queen, and “m” for male.

## Institutional abbreviations

The collection abbreviations follow Lattke (2000).

<b>FHGC</b>	Francisco Hita Garcia personal collection, Okinawa Institute of Science and Technology, Onna-son, Okinawa, Japan
<b>KSMA</b>	King Saud University Museum of Arthropods, Plant Protection Department, College of Food and Agriculture Sciences, King Saud University, Riyadh, Kingdom of Saudi Arabia.
<b>MCZC</b>	Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, U.S.A.
<b>WMLC</b>	World Museum Liverpool, Liverpool, U.K.

## Results

### Synoptic list of Arabian *Nesomyrmex* species

- Nesomyrmex angulatus* (Mayr, 1862) [Oman, Saudi Arabia, Yemen]  
 = *Nesomyrmex angulatus ilgii* (Forel, 1894)  
 = *Nesomyrmex latinodis* (Mayr, 1895)  
 = *Nesomyrmex angulatus concolor* (Santschi, 1914)  
*Nesomyrmex humerosus* (Emery, 1896) [Yemen]  
*Nesomyrmex zaheri* Sharaf, Akbar & Hita Garcia, sp. n. [Yemen]

### Identification key to Arabian *Nesomyrmex* species (workers)

- 1 Anterior clypeal lobe short, flat-margined, and never convex, lobe with a small median triangular projection (Fig. 2A); dorsal pronotum anterolaterally sharply marginate, with sharp, dentate corners; in profile mesosomal outline strongly concave (Fig. 2B); petiole barrel-shaped with weakly developed, short and triangular petiolar node (Fig. 2B) ..... ***N. humerosus***
- Anterior clypeal lobe always conspicuously developed, convex and rounded, never with a small median triangular projection (Fig. 2C); dorsal pronotum anterolaterally weakly marginate without sharp, dentate corners; in profile mesosomal outline flat and uninterrupted (Fig. 2D); petiole with very well developed petiolar node (Fig. 2D)..... **2**

- 2 Clypeus with median longitudinal carina (Fig. 3A); third mandibular tooth relatively larger and better developed (Fig. 3A) ..... *N. angulatus*  
 – Clypeus without median longitudinal carina (Fig. 3A); third mandibular tooth relatively smaller and reduced (Fig. 3B) ..... *N. zaheeri*

***Nesomyrmex angulatus* (Mayr, 1862)**

Figs 2C, D, 3A, 4

*Leptothorax angulatus* Mayr, 1862: 739 (w.). EGYPT. Santschi, 1914: 107 (q.). [Combination in *L. (Goniothorax)*: Emery 1896: 58 (footnote); in *Nesomyrmex*: Bolton 2003: 272. See also: Mbanyana and Robertson 2008: 38. Current subspecies: nominal plus *lybica*].

*Leptothorax angulatus* r. *ilgii* Forel, 1894: 82 (w.). ETHIOPIA. Santschi 1912: 148 (q.). [Combination in *L. (Goniothorax)*: Wheeler W.M. 1922: 891. Junior synonym of *N. angulatus*: Bolton 1982: 324].

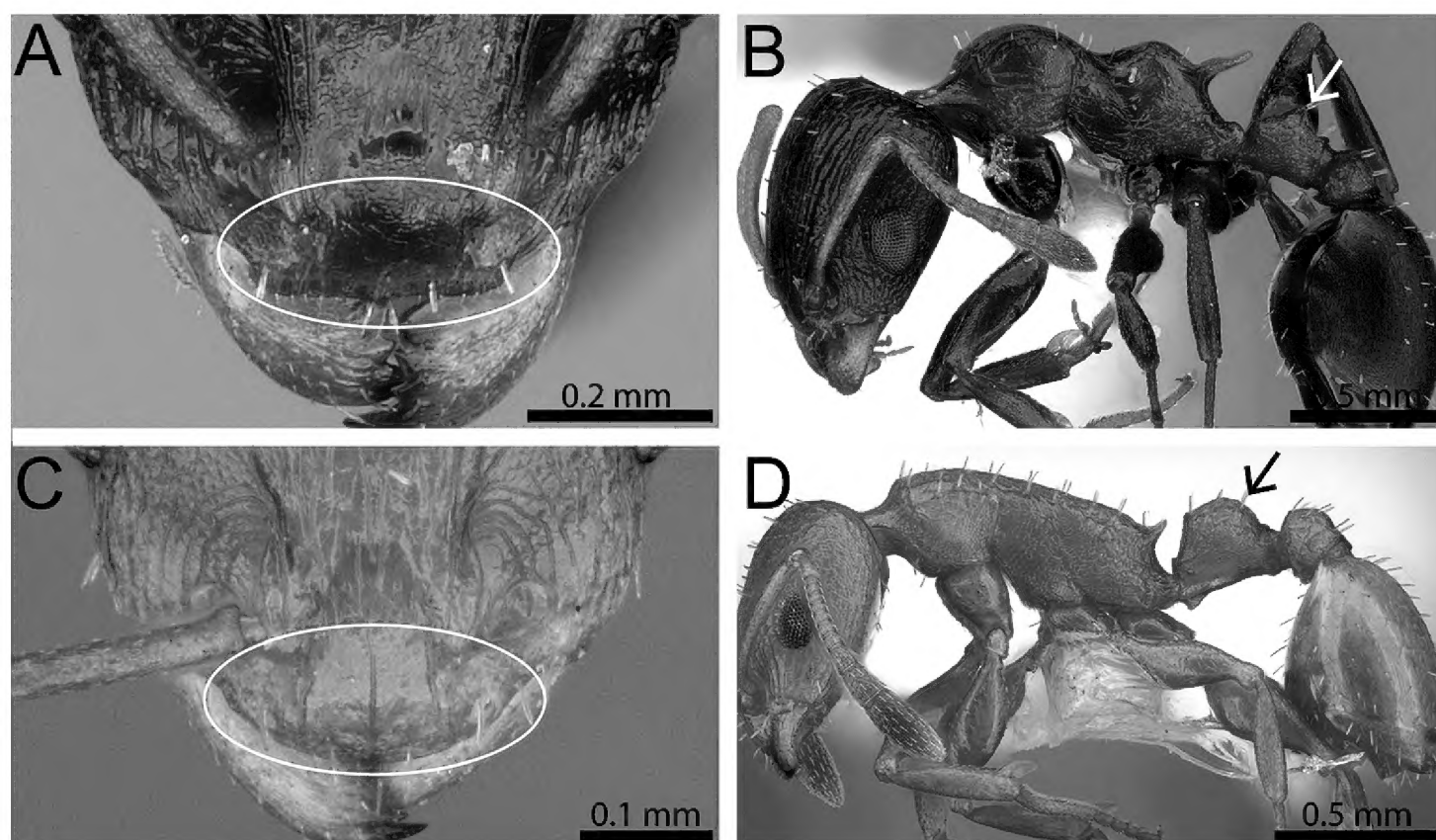
*Leptothorax latinodis* Mayr, 1895: 130 (w.). MOZAMBIQUE. [Combination in *L. (Goniothorax)*: Emery 1896: 58 (footnote). Junior synonym of *N. angulatus*: Bolton 1982: 324].

*Leptothorax angulatus* var. *concolor* Santschi, 1914: 107, fig. 15 (w.) KENYA. Emery 1915: 16 (q.m.). [Junior synonym of *N. angulatus*: Bolton 1982: 324].

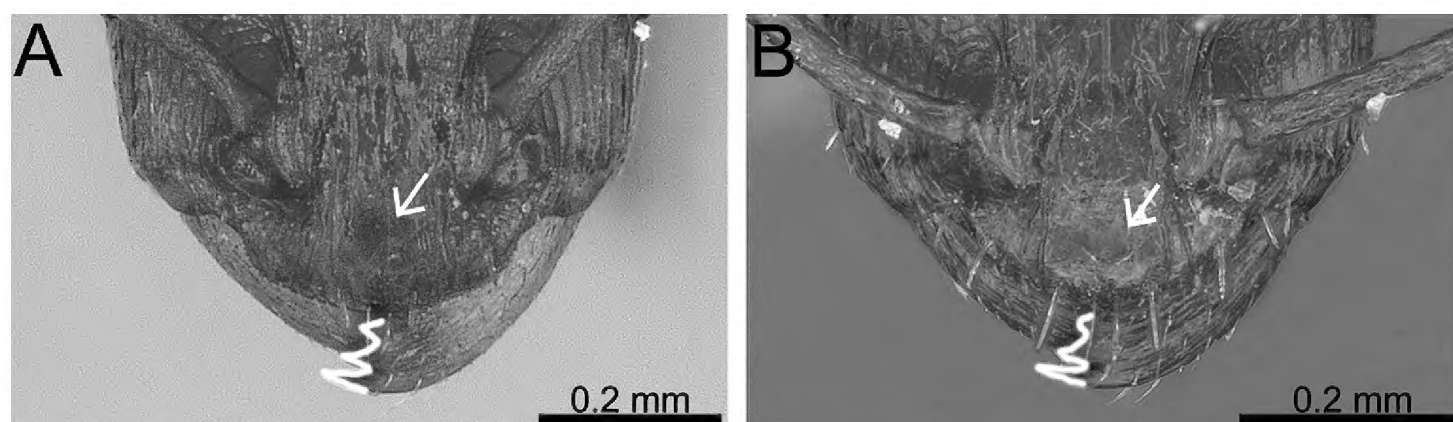
**Material examined.** KENYA: Coast Province, Malindi, Arabuko Sokoke Forest, -3.29, 39.98, 10–15 m, coastal hard wood forest, 24.V.2001 (*R.R. Snelling*) (FHGC: 3w); Coast Province, Malindi, Arabuko Sokoke Forest, -3.321, 39.929, 50 m, coastal dry forest, VI.2009 (*F. Hita Garcia* & *G. Fischer*) (FHGC: 3w); Rift Valley Province, Laikipia, Ewaso Ngiro, near Mpala Research Centre, 0.30, 36.91, 1600 m, *Acacia* woodland, 10.IV.2001 (*R.R. Snelling*) (FHGC: 10w); Rift Valley Province, Laikipia, Mpala Research Centre, 0.29, 36.9, 1650 m, *Acacia* woodland, 27.-28.IX.1999 and 24.III.2001 (*R.R. Snelling*) (FHGC: 3w); Western Province, Kakamega Forest, Buyangu Village, 0.3590, 34.8708, 1590 m, farmland, VII.2007 (*F. Hita Garcia*) (FHGC: 3w); MOZAMBIQUE: Sofala Province, Gorongosa National Park, Explore Gorongosa Park, -18.927, 34.378, 24 m, Fever tree forest, 20.V.2012 (*G.D. Alpert*) (MCZC: 3w); Sofala Province, Gorongosa National Park, 3 km W Chitengo, -18.992, 34.325, 37 m, riverine forest, 19.IV.2013 (*G.D. Alpert*) (MCZC: 3w); KINGDOM OF SAUDI ARABIA: Al Baha Province, Al Mukhwah, Dhi Ayn Archeological village, 19.929417°N, 41.441722°E, 741 m, 18.V.2010, (*M. R. Sharaf*) (KSMA: 3w); Elqamh park, Baljurshi, 19.913056°N, 41.905°E, alt. 1931 m, 17.V.2010, (*M. R. Sharaf*) (KSMA: 1w). Asir Province, Khamis Mushayt, W. Ben Hashbal, 18.594806°N, 42.650361°E, 1892 m, 26.IV.2011, (*M. R. Sharaf*) (KSMA: 6w); ZIMBABWE: Zebra Island, south side, -16.573, 28.901, 12.V.2012 (*J.K. Wetterer*) (FHGC: 1w).

**Diagnosis.** The following character combination distinguishes *N. angulatus* from the other members of the group in the Arabian Peninsula: third mandibular tooth





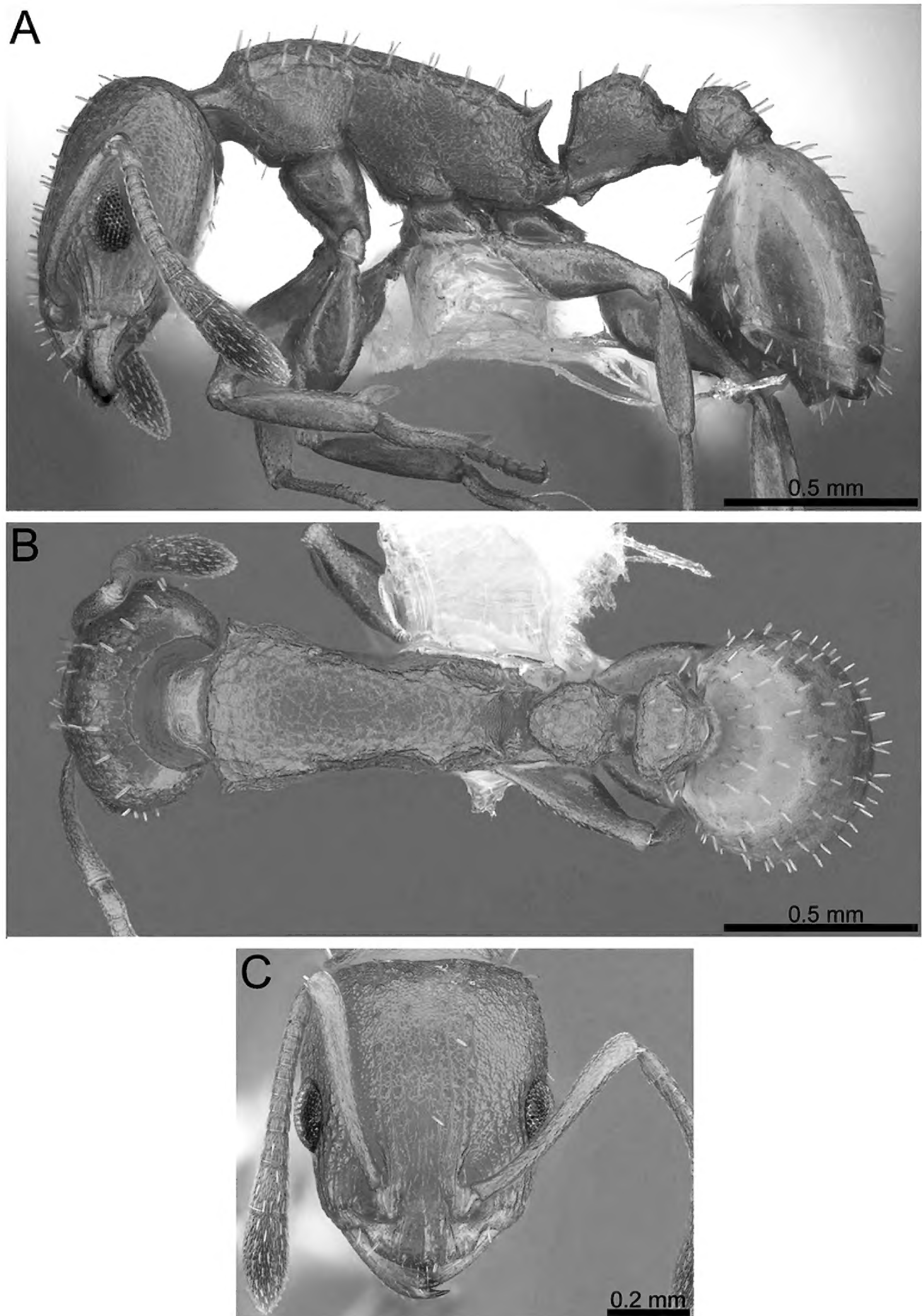
**Figure 2.** Anterior cephalic dorsum (white ellipse around anterior clypeus) and body in profile (arrows indicating petiolar node). **A, B** *N. humerosus* (CASENT0906196 – Antweb, Estella Ortega 2013) **C** *N. angulatus* (CASENT0235552 – Antweb, Shannon Hartman 2011) **D** *N. angulatus* (CASENT0922010 – Antweb, Zachary Lieberman 2015).



**Figure 3.** Anterior cephalic dorsum showing mandibles and clypeus (white lines outlining mandibular teeth and white arrows indicating median longitudinal carina or absence thereof). **A** *N. angulatus* (CASENT0235552 – Antweb, Shannon Hartman 2011) **B** *N. zaheiri* sp. n. (CASENT0906379 – Antweb, Estella Ortega 2013).

relatively larger and better developed; anterior clypeal lobe always conspicuously developed, convex and rounded, never with a small median triangular projection; clypeus with median longitudinal carina; pronotum anterodorsally without sharp, dentate corners; in profile mesosomal dorsum forming a single, uninterrupted flat surface without any trace of metanotal groove; petiole with very well developed node.

**Worker measurements (n=19).** HL 0.70–0.91; HW 0.55–0.71; SL 0.50–0.67; EL 0.17–0.22; PH 0.26–0.41; PW 0.37–0.57; WL 0.75–1.21; PSL 0.05–0.14; PTL 0.17–0.27; PTH 0.20–0.34; PTW 0.20–0.34; PPL 0.15–0.26; PPH 0.17–0.30; PPW



**Figure 4.** *Nesomyrmex angulatus* (CASENT0922010 – Antweb, Zachary Lieberman 2015). **A** Body in profile **B** Body in dorsal view **C** Head in full-face view.



0.25–0.40; OI 27–35; SI 88–97; CI 76–86; DMI 44–56; LMI 30–37; PSLI 6–16; LPeI 57–88; DPeI 114–137; LPpI 68–91; DPpI 154–188; PPI 111–160.

**Distribution.** As already pointed out by Hita Garcia et al. (2017), this species has the widest distribution of any species of the *N. angulatus* group, and is certainly the most widespread *Nesomyrmex* species worldwide. *Nesomyrmex angulatus* has been reported from most African countries, as well as on the Arabian Peninsula and most of the Malagasy Region. The species seems to prefer comparatively arid environments and is predominantly found in cavities of dead wood, trunk of trees, lower vegetation and rarely on the ground (Bolton 1982; Mbanyana and Robertson 2008).

**Comments.** This species exhibits remarkable variability throughout its distributional range, most notably in the shape of the petiolar node (Bolton 1982, Hita Garcia et al. 2017), but it is also relatively variable in body size and eye size. It is likely that the material currently understood to be *N. angulatus* is actually a complex of cryptic species. However, in order to examine this question in detail it would be necessary to gather substantial material from throughout its whole distribution range from numerous museum collections. Despite that this is a highly desirable undertaking; it is outside the scope of the current study that focuses on the Arabian fauna only.

### *Nesomyrmex humerosus* (Emery, 1896)

Figs 2A, B, 5

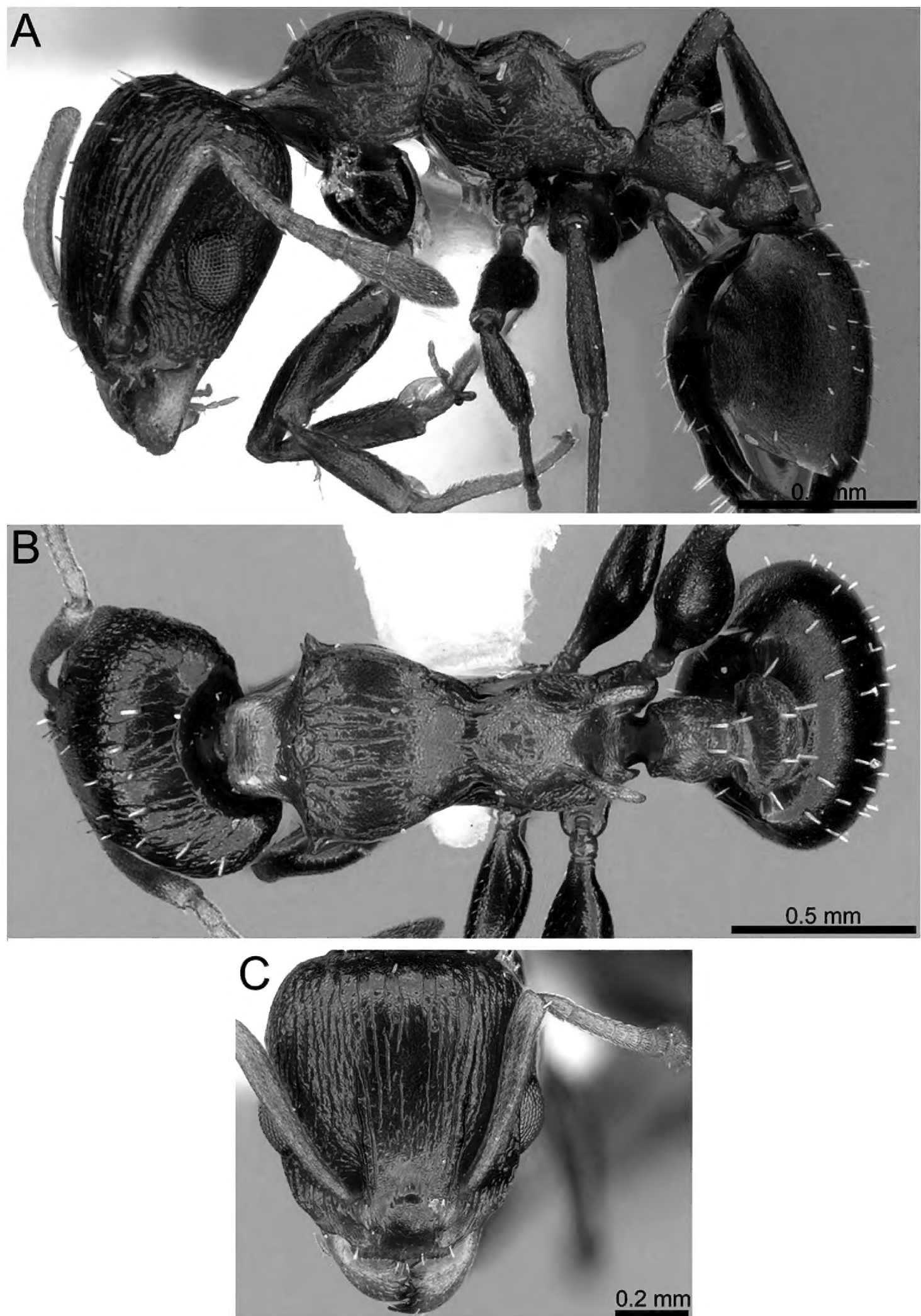
*Leptothorax* (*Goniothorax*) *humerosus* Emery, 1896: 62 (w.) EAST AFRICA (no locality given, very likely KENYA). [Combination in *Nesomyrmex*: Bolton 2003: 272. See also: Bolton 1982: 329; Hita Garcia et al. 2017: 8].

**Material examined.** KENYA: Coast Province, Malindi, Arabuko Sokoke Forest, -3.321, 39.929, 50 m, coastal dry forest, VI.2009 (F. Hita Garcia & G. Fischer) (FHGC: 3w, 1q).

**Diagnosis.** The following character combination distinguishes *N. humerosus* from the other members of the group in the Arabian Peninsula: anterior clypeal lobe short, flat-margined, and never convex, with small median triangular projection; clypeus without median longitudinal carina; pronotum anterodorsally sharply marginate, with sharp, dentate corners; in profile mesosomal outline conspicuously concave; petiole barrel-shaped with very weakly developed, short and triangular petiolar node.

**Worker measurements (n=3).** HL 0.74–0.75; HW 0.70–0.71; SL 0.58–0.59; EL 0.27–0.28; PH 0.34–0.35; PW 0.52–0.53; WL 0.89–0.92; PSL 0.19–0.20; PTL 0.12–0.13; PTH 0.24–0.25; PTW 0.21–0.22; PPL 0.15–0.16; PPH 0.21–0.22; PPW 0.33–0.34; OI 39; SI 83; CI 95; DMI 58; LMI 38; PSLI 26–27; LPeI 50–52; DPeI 169–175; LPpI 71–73; DPpI 213–220; PPI 155–157.

**Distribution.** *Nesomyrmex humerosus* is currently only known to occur in Kenya, Tanzania, and Yemen. Very little is known about the biology of the species. Rarely collected species seems to live on vegetation but has also been sampled from the ground (Hita Garcia et al. 2017).



**Figure 5.** *Nesomyrmex humerosus* (CASENT0906196 – Antweb, Estella Ortega 2013). **A** Body in profile **B** Body in dorsal view **C** Head in full-face view.

**Comments.** *Nesomyrmex humerosus* is the only member of the *N. humerosus* group and possesses an unusual character combination for an Afrotropical species due to its flat anterior clypeal margin, dentate pronotum, and barrel-shaped petiole. For more details see Hita Garcia et al. (2017). This species has been infrequently collected and is apparently known from four separate collections. More intensive sampling in East Africa and Yemen should yield more material. It is noteworthy that we were not able to examine any material of this species from Yemen and all our knowledge of the species is based on literature (Collingwood and Agosti 1996, Borowiec 2014).

***Nesomyrmex zaheri* Sharaf, Akbar & Hita Garcia, sp. n.**

<http://zoobank.org/178FA74B-1C5D-41E5-87B7-8CC5811EFA4B>

Figs 3B, 6

**Type material. Holotype**, pinned worker, YEMEN: Al Kawd, 13.088622° N, 45.364722° E, light-trap, 6770, 07.IX.2001, (*A. van Harten*) (WMLC: CASENT0906379).

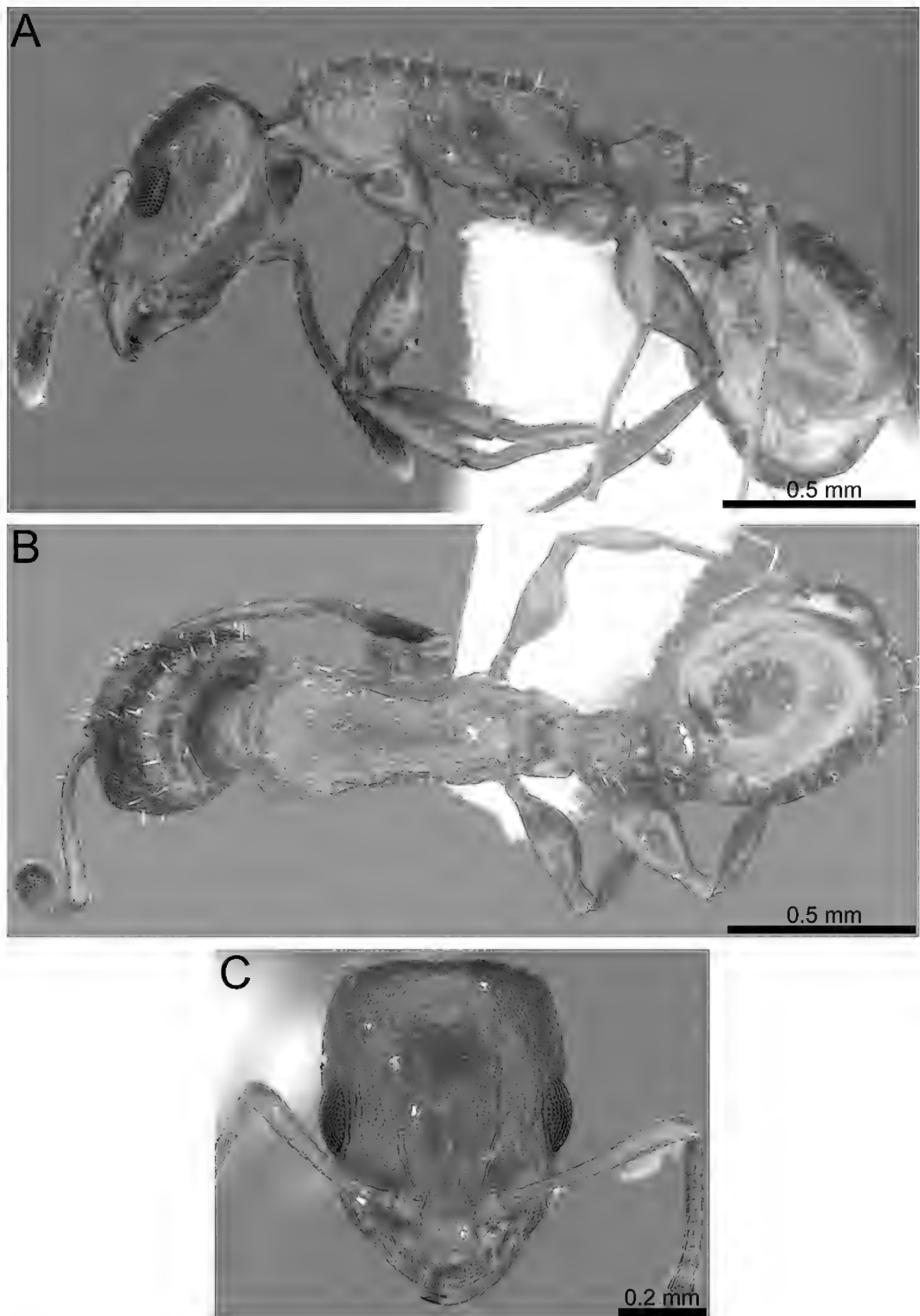
**Diagnosis.** The following character combination separates *N. zaheri* from the other *Nesomyrmex* species known from the Arabian Peninsula: third mandibular tooth relatively smaller and reduced; anterior clypeal lobe always conspicuously developed, convex and rounded, never with a small median triangular projection; pronotum anterodorsally without sharp, dentate corners; clypeus without median longitudinal carina; in profile mesosomal dorsum forming a single, uninterrupted flat surface without any trace of metanotal groove; petiole with very well developed node.

**Description. Holotype worker measurements.** HL 0.71; HW 0.55; SL 0.49; EL 0.17; PH 0.30; PW 0.42; WL 0.83; PSL 0.07; PTL 0.17; PTH 0.21; PTW 0.18; PPL 0.12; PPH 0.21; PPW 0.24; OI 31; SI 89; CI 77; DMI 51; LMI 36; PSLI 10; LPeI 81; DPeI 106; LPpI 57; DPpI 200; PPI 133.

**Head.** Masticatory margin of mandible with four teeth, decreasing in size from largest, acute apical tooth to smallest basal denticle; clypeus smoothly arched-convex and without a small median triangular projection; head in full-face view appearing almost rectangular, longer than broad (CI 77), sides of head almost straight, broader posteriorly behind eye level and narrowest directly behind posterior eye margin; posterior head margin slightly concave medially; frontal carinae and antennal scrobes absent; antennal scapes short, not reaching posterior head margin (SI 89). Eyes of moderate size (OI 31), with eight to nine ommatidia in the longest row.

**Mesosoma.** In lateral view mesosomal outline relatively low (LMI 36) and flat without any metanotal groove; promesonotal suture present laterally and completely absent dorsally; pronotum marginate between lateral and dorsal mesosoma, anterodorsal corners slightly denticulate; propodeum armed with short propodeal teeth (PSLI 10); propodeal lobes moderately developed and rounded.

**Waist segments and gaster.** Petiolar peduncle moderate short; in profile petiolar node relatively high and narrowing from base to apex, around 1.2 times as high as long



**Figure 6.** *Nesomyrmex zaheeri* sp. n. (CASENT0906379 – Antweb, Estella Ortega 2013). **A** Body in profile **B** Body in dorsal view **C** Head in full-face view.

(LPeI 81); anterior and petiolar faces truncate; node in dorsal view weakly wider than long (DPeI 106) and denticulate; in profile postpetiole globular, about 1.8 times as high as long (LPpI 57); in dorsal view about twice as wide as long (DPpI 200); postpetiole in dorsal view around 1.3 times as wide as petiolar node (PPI 133).

**Sculpture.** Mandibles shagreened with prominent but weak, irregular, longitudinal rugulae; median clypeal carina absent, two lateral, longitudinal, rugae on each side; cephalic dorsum posteriorly and laterally weakly reticulate-rugose, medially mostly with conspicuously reticulate-punctulate ground sculpture; mesosoma laterally and dorsally with distinct reticulate-punctulate ground sculpture, lateral mesosoma also with few conspicuously longitudinal rugae; dorsum reticulate-rugose with some irregular, longitudinal elements medially; legs unsculptured, smooth and shining; petiole and postpetiole with prominent reticulate-rugose sculpture superimposed on reticulate-punctulate ground sculpture; gastral tergites mostly smooth and shiny.

**Pilosity and pubescence.** Head, mesosoma, waist segments and gaster dorsally with stout, erect, blunt, and moderately short pilosity; head laterally and ventrally with short appressed to decumbent pubescence; pubescence on mesosoma and waist segments sparse to absent; gastral tergites with short appressed to decumbent pubescence.

**Coloration.** Body uniformly light brown with head darker and the appendages lighter in colouration.

**Etymology.** The patronym *zaheri* has been selected to honor the late famous Egyptian Qura'an reader Sheikh Abdel-Azim Zaher (1904–1971).

**Distribution.** At present the new species is only known from the type locality, which is located near the Indian Ocean in southwestern Yemen near Aden. Nothing is known about the biology or nesting behavior of the species.

**Comments.** The new species is clearly a member of the *N. angulatus* species group sensu Hita Garcia et al. (2017). It is the third species known from the Arabian Peninsula and can be well separated from the other two species by the characters given in the key. *Nesomyrmex zaheri* can be easily distinguished from *N. humerosus*. However, *N. zaheri* and *N. angulatus* are morphologically very similar and differ only by a few morphological characters. As noted above, *N. zaheri* differs from *N. angulatus* by the lack of a median clypeal carina and a much shorter third mandibular tooth. In addition, *N. zaheri* has a slightly wider (DPpI 200 vs. 154–188) and higher (LPpI 57 vs. 68–91) postpetiole. These measurements may be found to overlap if additional specimens of *N. zaheri* become available. It is possible that the holotype of *N. zaheri* may be a geographical variant of the widespread *N. angulatus*. However, we examined several hundred *N. angulatus* from throughout its recognized geographical distribution and all specimens possessed a median clypeal carina, a character, which is usually stable in ants.

## Discussion

*Nesomyrmex* is broadly distributed throughout the Afrotropical and the Malagasy Regions (Fisher and Bolton 2016). Of the two species treated here, *N. angulatus* is



widespread but predominantly Afrotropical and *N. humerosus* has been reported from Kenya and Tanzania (Hita Garcia et al. 2017). Despite being supposedly endemic to Yemen, the new species is a member of the Afrotropical *N. angulatus* species group. Consequently, all three species treated in this study confirm a strong Afrotropical faunal influence and provide further evidence that the southwest of the Arabian Peninsula can be considered as the northeastern limit of the Afrotropical Region (Bolton 1994, Robertson 2000).

Due to the position of the Arabian Peninsula in the interchange of three biogeographical regions, the Palearctic, Oriental, and Afrotropical, it is not surprising to observe shared faunal elements between these regions. The southwestern mountains of the Kingdom of Saudi Arabia and Yemen exhibit strong biogeographical affinities with the Afrotropical fauna (Eig 1938, Zohary 1973, Lehrer and Abou-Zied 2008, Doha 2009, Aldawood et al. 2011, Sharaf and Aldawood 2011, Sharaf and Aldawood 2012, Sharaf et al. 2012a, b, El-Hawagryi et al. 2013, Sharaf and Aldawood 2013, Sharaf et al. 2014).

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